AN INVESTIGATION OF SITUATION AWARENESS USING AVIATION INCIDENT REPORTS

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ABSTRACT

This research was performed to determine the factors which affect the quality of situation awareness (SA) in civilian aircrew members. The recent popularity and increased investigation of SA has forced the research community to be very specific in modeling how it enhances decision-making in complex, dynamic environments. This research sought to better understand the effects of poor communication, high workload and time pressure on losses of SA for teams and individuals. Based upon Endsley's (1995a) model of SA and an analysis of aviation incident reports, it was found that 205 of the 590 incident reports investigated involved a loss in SA. This implies that SA is indeed a significant factor affecting aviation decision-making. Further, the results show that instances of poor communication and high workload occur in significantly higher proportions of team comprehension errors. These findings point to both the usefulness of Endsley's (1995a) model and the usefulness of using incident report data for the understanding of SA.

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DEDICATION

This thesis is dedicated to my future wife, Mona Sinno and my immediate family: Kenneth Gibson, Libby Gibson, Shannon Gibson, Jon Barnes, Bryan Gibson, and Amanda Gibson. Without their love and support, I would not have been able to accomplish the successes I have experienced thus far in life. Thank you.

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CHAPTER I

INTRODUCTION

A significant amount of recent research has assessed the situation awareness (SA) of people who are involved in work environments which are considered "dynamic, complex, high information loaded, variably workloaded, and risky" (Gaba, Howard, and Small, 1995, p. 20). Specifically, researchers have been trying to determine the aspects of the construct and ways in which to best train individuals to improve their situation awareness. This construct, which can be viewed as a state, known as SA, has taken the both the military and civilian research communities by storm (Dominguez, 1994). A somewhat unified definition of SA has emerged in the literature. SA is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995a, p. 36). SA is a product or cognitive state that exists after one has assessed the environment and the information it affords at a particular point in time.

This definition is certainly not the only definition which has been presented addressing the construct of SA. Other researchers from various backgrounds have provided their own definitions and subsequent theories to describe this construct (Dominguez, 1994). Researchers have defined SA as "externally directed consciousness " (Smith and Hancock, 1995), "a label describing a number of cognitive processes that are critical to dynamic, event-driven, and multitask fields of practice" (Sarter and Woods, 1995), or even "a pilot's continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the capability to forecast, and

execute tasks based on that perception" (Vidulich, 1994). As one can see, these definitions while different, do share some theoretical underpinnings.

Within the context of this research, the author has chosen to focus on the model presented by Endsley (1995a). Endsley's model is the most theoretically developed and widely tested to date. Further research of her model may be most beneficial for the sake of advancement of theory and knowledge concerning the construct of SA.

Situation Awareness

One may wonder, in what circumstances may SA be critical? Consider the following real world example of team SA:

"Date: December 29, 1972
Type: Lockheed L-1011
Registration: N310EA
Operator: Eastern Air Lines
Where: Miami, FL
Report No. NTSB-AAR-73-14
Report Date: June 14, 1973
Pages: 45

An Eastern Air Lines Lockheed L-1011 crashed at 2342 eastern standard time, December 29, 1972, 18. 7 miles west-northwest of Miami International Airport, Miami, Florida. The aircraft was destroyed. Of the 163 passengers and 13 crewmembers aboard, 94 passengers and 5 crewmembers received fatal injuries. Two survivors died later as a result of their injuries.

Following a missed approach because of a suspected nose gear malfunction, the aircraft climbed to 2,000 feet mean sea level and proceeded on a westerly heading. The three flight crewmembers and a jumpseat occupant became engrossed in the malfunction.

The National Transportation Safety Board determined that the probable cause of this accident was the failure of the flightcrew to monitor the flight instruments during the final 4 minutes of flight, and to detect an unexpected descent soon enough to prevent impact with the ground.

Preoccupation with a malfunction of the nose landing gear position indicating system distracted the crew's attention from the instruments and allowed the descent to go unnoticed.

As a result of the investigation of this accident, the Safety Board has made recommendations to the Administrator of the Federal Aviation Administration." (NTSB, 1973).

From this report, one can note that the perception of information in the environment, the comprehension of what that information means, and the projection of future possible status of an aircraft is extremely important and, apparently, sometimes difficult.

Accidents such as these have been the driving force behind the study of SA. Vidulich (1994) has pointed out that it is not just other researchers who would like to understand this construct, but also aviation pilots. Pilots were a major impetus behind SA research because traditional human information processing research has not provided pilots the answers and training interventions needed to deal with the difficulties of working in dynamic environments (Vidulich, 1994). The current question is no longer whether SA exists, but rather what are the components of SA, the factors which may effect it, how should SA be measured, and how can it be improved through training.

Most of the current research describing SA has centered around pilots, specifically US Air Force and US Navy jet pilots (Endsley, 1995a). The current database of information purports that "in the flight environment, the safe operation of the aircraft in a manner consistent with the pilot's goals is highly

dependent on a current assessment of the changing situation,....aircraft operational parameters, external conditions, navigational information, other aircraft and hostile factors" (Endsley, 1995a, p. 49). Thus, if the pilot or individual in a complex environment is not totally aware of all of the factors around him or her, performance may decline and the goals of work may not be achieved.

Endsley's Theory of Situation Awareness

Researchers have begun to develop the theory behind SA and the factors which may have an effect on SA in dynamic and complex environments. Endsley (1995a) offers a comprehensive theory of SA including the role of environmental and cognitive factors. This model is shown as Figure 1.

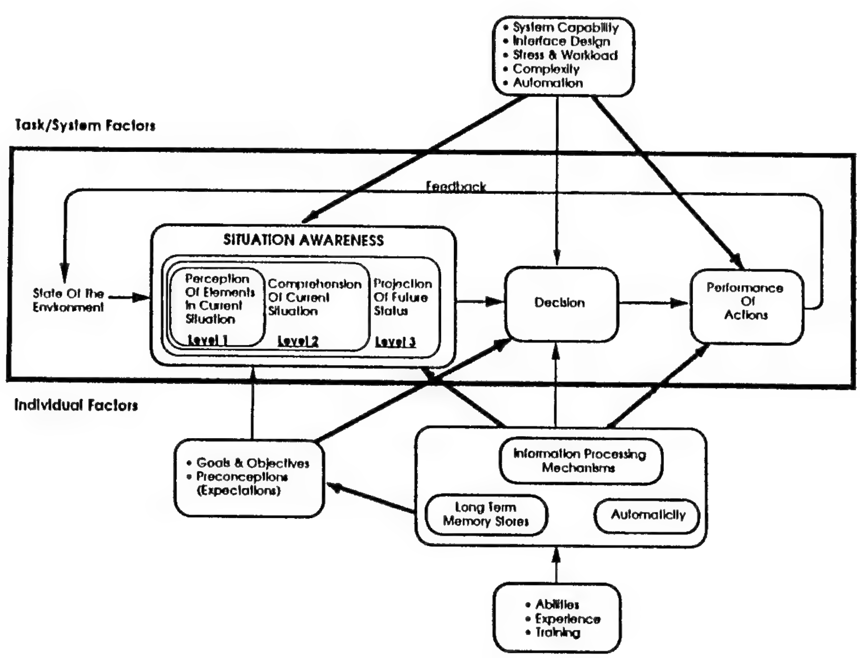

Figure 1. Endsley's (1995a) Model of Situation Awareness.

Her model presents a number of factors which can have an effect upon one's ability to maintain SA including the perception and comprehension of the current environment, and projection of future status of the activities in a dynamic environment.

As one can see from Figure 1, Endsley's model corresponds to the human-machine interface model depicted in most introductory human factors psychology books (Proctor and Van Zandt, 1994; R. Nowaczyk, personal communication, September 19, 1996). She shows that both the environment, being the Task/System Factors, and the Individual Factors will both have an impact upon one's or a team's SA at the interface of the two. The external environmental factors which will have an effect on SA are workload, numerous forms of stress (time pressure, company pressure, etc.), interface design, task complexity, and automation. The internal factors which will have an effect upon SA will be experience, communication, pre-attentive processing, attention, working memory, perception, long-term memory, automaticity, one's goals, and mental models (Endsley, 1995a). While this list of factors may seem to be somewhat of a laundry list of possible factors affecting SA, one must remember that this construct is the combination of three very important cognitive processes working in conjunction with each other, those being perception and comprehension of information, and projection of future status. By examining how SA might work in a specific situation, one can better understand how these

factors might affect SA. The following is an example of how SA would be utilized to enhance decision-making while flying an advanced jet aircraft:

> "A pilot may perceive several aircraft recognized as enemy fighter jets that are approaching in a particular spatial arrangement. By pattern matching to prototypes in memory, these separate pieces of information can be classified as a particular recognized aircraft formation. According to an internally held mental model, the pilot is able to generate probable attack scenarios for this type of formation when in relation to an aircraft with the location and flight vector of his or her ownship. Based on this high level of SA, the pilot is then able to select the prescribed tactics that dictate exactly what evasive maneuvers should be taken." (Endsley, 1995a, p. 44.)

While this example is geared toward those in the fighter aircraft community, one can see that SA has three distinct levels: perception (seeing the aircraft), comprehension (recognizing those aircraft as enemy fighters), and projection of future status (generations of attack possibilities ultimately linked with performance). In the following sections, these factors are examined in greater detail.

Factors Proposed to Affect Situation Awareness

Internal Factors

Attention

As Endsley states, "in complex and dynamic environments, attention demands resulting from information overload, complex decision-making, and multiple tasks can quickly exceed a person's limited attention capacity" (1995a, p. 41). Objects in a dynamic environment will largely effect one's momentary

SA. While the number of tasks which may be completed successfully simultaneously varies, previous research has shown that, in general, as the number of extra activities a human operator is forced to accomplish simultaneously increases, performance on a primary task is adversely affected (Proctor and Van Zandt, 1994). Specifically, it has been found that multiple sources of data can be monitored by a human operator in a comparatively efficient manner. However, one's ability to monitor multiple sources of data declines as information is received simultaneously from numerous sources (Proctor and Van Zandt, 1994).

One of the most relevant theories of attention for the discussion of SA is the multiple resource theory of attention by Wickens (1992). This theory "argues that instead of one single supply of undifferentiated resources, people have several different capacities with resource properties" (Wickens, 1992, p. 375). Different modalities of input (visual and auditory) and different processing codes (spatial and verbal) exist to allow the human to complete multiple tasks successfully and attend to different pieces of information as long as the tasks use differing resources. As the demand of resources increases, performance decreases on complex tasks. This theory explains to an adequate degree how time-sharing between different attentional demands can occur without difficulty given adequate time and resource allocation. Attentional demands may be somewhat high for SA if the human must allocate the same resources to attend to

numerous pieces of information or process them within the same or competing processing codes (Endsley, 1995a).

Working Memory

While attention is crucial for SA, human working memory capacity may be the most important factor affecting SA. Recent work by Baddeley (1995) has shown both the capacity and limitations of human working memory. Baddeley's model of working memory postulates that a central executive exists for attentional control which is supported by two storage systems, the visuo-spatial sketchpad and a phonological loop. The central executive is responsible for strategy selection and planning (Baddeley, 1995). This component of working memory is thought to be the link between the two different storage systems. The visuospatial sketchpad is a storage system responsible for holding nonverbal spatial information in working memory. The phonological loop would be the sketchpad's counterpart, responsible for working storage of verbal information. Because humans have only a limited working memory capacity (Anderson, 1995; Baddeley, 1995; Endsley, 1995a) only a limited number of mental tasks can be accomplished at one specific time. Working memory is relevant for SA as it may prove to be a limitation for SA as spatial or verbal information may overload working memory storage capacity as well as the central executive, which may lead to poor SA.

Long-Term Memory and Experience

Long-term memory and experience are hypothesized to also influence SA. Experience has long be contended as a significant predictor of performance in many contexts. Within the realm of cognitive psychology, experience and expertise have been the subject of numerous studies (Anderson, 1995). Researchers have determined that as practice occurs within problem solving, skill-based production, or physical activities such as sports, a power law of learning exists (Anderson, 1995). This law suggests that as people practice their actions, they learn at exponential rates until further practice has no real benefit.

One might wonder how experience may effect SA. It has been hypothesized that as pilots or people working in other dynamic environments complete their daily duties routinely, they store and retain the problems they face within their daily jobs in long-term memory. This effect is synonymous with the study of expert chess players who do not remember the moves for individual chess pieces, but rather a pattern of moves for several pieces (Anderson, 1995).

Studies have shown that as players increase their knowledge of the game over long periods of time and build on their experience, they store these patterns of moves in long-term memory allowing for a reduction in errors while playing and for better strategic planning capabilities (Anderson, 1995). Schema formation occurs. An application of this concept for SA would suggest that if a pilot is inexperienced with an aircraft, the copilot, a certain approach, or any

number of distracters on the flight deck, SA will suffer due to a lack of information (patterns, scripts, mental models, schemata) stored in long-term memory. One will have to focus more attention on solving individual problems continuously which could easily lead one to become "behind the plane" or have poor quality SA. Having long-term storage of information relevant to a dynamic and rapidly changing environment should definitely improve SA.

Automaticity

Automaticity is also an important contributor to the experience/expertise factor. Again, cognitive researchers have shown that as actions are continually practiced they can become automatic, that is, requiring no conscious attentional resources. One of the seminal experiments of this phenomenon was conducted by Schneider and Shiffrin (1977). Subjects were required to scan visual displays for a certain target (letter). With vast amounts of practice, the experimenters found that the experimental task became automatic for the subjects in that task completion did not require conscious effort or attentional resources (Schneider and Shiffrin, 1977).

This same phenomenon is experienced by most drivers everyday. One can often remember occurrences where one appears inattentive during the drive home. Even complex tasks such as driving a car or piloting an aircraft can be automatized to some degree. According to the theory of SA, one who completes a drive in this manner is still maintaining SA, perhaps unconsciously. It has been

shown, for instance, that feature detection and synthesis (an automatic process) occur as a function of how familiar those patterns are to a person (LaBerge, 1973). When unexpected stimuli are presented, the driver shifts from automatic to controlled processing which uses working memory and attentional resources. Thus, SA may be influenced by both automatic and controlled (conscious and effortful) processing.

Endsley's theory of SA proposes that even complex tasks such as driving may not provide adequate salience to be recalled if only familiar stimuli were encountered on a drive home (1995a). However, as automaticity may lessen the attentional demands and increase the chances that SA will be maintained, one must consider how unfamiliar stimuli such as a hysterical passenger on an aircraft may affect a pilot's or crew's SA, or how the unexpected rise and fall of two distinct physiological parameters may affect an anesthesiologist's SA. Research conducted by LaBerge (1973) has shown that with unfamiliar stimuli, the attention shift to an unexpected pattern requires time and controlled attentional resources. However, with significant practice, one can complete this shift to recognize new patterns when primed. However, this research was conducted in a static environment (laboratory with simple pattern recognition tasks). Research in dynamic environments is needed to determine if automatic processes will be affected by changing conditions.

Environmental Factors

Workload

According to Endsley's theory, the main moderating variable for SA will be one's workload, especially one's mental workload (1995a). While Endsley (1993) has shown that the constructs of SA and workload can diverge, the assumption remains that as workload increases, the operator must expend effort and attention to achieve SA. Therefore, SA is likely to suffer.

A prime example of how workload should affect SA is seen in one of the most prominent findings of psychology, the Yerkes-Dodson Law (Yerkes and Dodson, 1908). The main findings of this law show that as arousal increases, complex task performance first increases, but then rapidly decreases. Because SA is to be maintained in a complex and dynamic environment, as arousal level increases, one's ability to project the future status of the dynamics of a situation should suffer. This finding has been attributed to the relationship between workload and attention. Researchers have shown that as arousal increases, a phenomenon known as perceptual narrowing occurs which causes one's attention to become more focused (Proctor and Van Zandt, 1994). "The ability to discriminate between relevant and irrelevant cues decreases.....at high arousal levels the allocation of attention is controlled by fewer and often less appropriate features of the situation" (Proctor and Van Zandt, 1994, p. 196-197).

The Team and Situation Awareness

Researchers have explored individual SA, however, team SA is thought to be a much more complex entity than individual SA simply because of the added team element (Salas, Prince, Baker, and Shreshtha, 1995). To understand this phenomenon of team SA, several researchers have investigated both the literature concerning teams, and also that of SA in order to develop a strong and guiding definition of this construct for further study.

These researchers first describe the concept of a team in order to lead to the development of team SA. The team is defined as "a set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership" (Salas, Dickinson, Converse, and Tannenbaum, 1992). Working with this constraint of "team," the definition of team SA can be described as a "dynamically changing state affected by the process of situation assessment and other team process behaviors, the level of each members own individual SA, and most importantly the level of shared understanding among team members" (Stout, Cannon-Bowers, and Salas, in press). Within this definition of team SA lies a very important piece of information. In order to truly have team SA, a team must have a <u>shared</u> understanding of the environment, a <u>shared</u>

understanding of the factors affecting that environment, and a shared future projection of how to deal with the factors in that environment (Endsley, 1995b).

Do teams that have a higher level of team SA out perform those teams which do not have a high degree of SA? While the research in this area is very recent, it seems to indicate that the more SA a team possesses, the better the team will perform. Specifically, research has shown that aviation crews which have a higher degree of communication and situation assessment (constructs linked to team SA) have better performance (Orasanu, 1995a).

Orasanu reviewed the utterances of high-performing and low-performing aircrews when they were faced with high levels of information overload emergency situations in a flight simulator. This research found high-performing crews performed more information gathering and planning when faced with dynamic problem conditions than low-performing crews. It is assumed from these data that the high-performing crews understood the situation surrounding them to a higher degree than low-performing crews. The high-performing crews "engaged in more planning... which essentially reflected their SA to prepare for what may develop or for high workload episodes" (Orasanu, 1995a, p.5). While this finding seems extremely plausible, the samples were limited in number restricting the external validity of this result. This research, however, shows the potential importance of team SA in team situations.

A recent review of the literature on team SA by Stout et al., (in press) examined studies of team SA and performance in dynamic settings. The researchers reviewed seven articles dealing with team SA and found that in each case, team SA was significantly related to team performance. It is important to note that specific team process behaviors moderated the relationship between team SA and performance. These team process behaviors included active communication, information gathering after critical decisions had been made in the team task, and pre-planning task objectives (pre-briefing) (Stout et al., in press). It seems as though team SA is a crucial construct that must be maintained in order for teams to perform well.

Time Pressure

As with workload, time pressure is hypothesized to be a stressor which should have a detrimental effect upon SA. Endsley's model assumes that under the stress of time pressure, operators may be forced to adopt a narrower span of attention, or to make decisions in a premature manner where a failure to explore an integrate all relevant information has occurred. Endsley (1995a) goes on to say that this narrowing of attention will significantly negatively affect the perception of information.

Recent studies into the effects of stress on team and individual decision making have found that under the stress of time pressure (as well as other forms of stress), teams experience a loss in team perspective as well as a decrement in

task performance (Driskell, Johnston, and Salas, 1994). What this suggests for SA is that in a team environment, as stress increases through time pressure, a narrowing of team perspective or decrease in shared understanding of the task can occur. Thus, it can be seen that stress factors such as time pressure should have varying effects upon both individual and team SA.

Errors in Situation Awareness

Within Endsley's model, SA is described in terms of levels or components. The levels are (1) perception of the environmental invariants in a volume of space and time, (2) the comprehension of that information for meaningfulness, and (3) the projection of near future status based on information presented (Endsley, 1995a). These three levels of SA are important because each level can and should have specific types of errors associated with it. Endsley (1995a) lays out the types of errors which may occur in each of these levels.

Within Level 1 of SA, operators must perceive the information around them in order to have higher quality SA. Thus, the main error which would occur in this level would be missing information which is needed to maintain SA (Endsley, 1995a). The Eastern Air Lines L-1011 crash mentioned earlier demonstrates how a lack of information can lead to poor quality Level 1 SA and poor performance. As the crew focused its attention on the landing gear indicator light, no information was gathered concerning the slow descent of the

plane. This narrowing of attention among the crewmembers led to the poor quality SA and subsequent disaster.

Level 2 SA is characterized as the comprehension of information which is acquired during the previous level of SA. Endsley (1995a) states that most instances of poor SA will be at Level 2 and occur as a result of "inability to properly integrate or comprehend the meaning of perceived data in light of operator goals" (p. 55). She goes on to state that this inability to properly integrate information could be due to inexperience with a situation where the operator lacks the scripts and schemata in long-term storage to effectively deal with the information, or a person will select the wrong mental model from memory to interpret the available information, thus leading to misinterpretation of information.

In a recent review of the 37 fatal accidents involving US airline carriers, the National Transportation Safety Board (NTSB) determined that 51 of the 302 classified errors which occurred during these flights were attributable to poor tactical decision-making (NTSB, 1994). Here, tactical decision-making was classified as "failing to change a course of action in response to signal to do so; failing to heed warnings or alerts that suggest a change in course of action" (NTSB, 1994, p. 47). According to theory, these error types would most likely have occurred as the crew members misinterpreted perceived information, a Level 2 SA error.

The third level of SA is characterized as the projection of near future status based on the information presented to an operator. This information should help an operator make better and more efficient decisions in the face of a changing environment. Endsley (1995a) theorizes that errors affecting this level of SA would occur because the operators do not have a highly developed mental model of a situation, or they are simply not proficient at mental simulation. According to a list of possible actions which may occur as a result of having Level 3 SA, Orasanu (personal communication, June 25, 1996) states that crewmembers would prioritize and assign duties to others, alert or warn their fellow crewmembers, or make contingency plans based on the information they had interpreted.

This taxonomy of actions seems to have some validity as the most frequent error made by crewmembers in fatal accidents from 1978-1990 were resource management errors (NTSB, 1994). Resource management errors are characterized as "failing to assign task responsibilities or distribute tasks among crewmembers; failing to prioritize task accomplishment; overloading crewmembers; failing to transfer/assume control of the aircraft" (NTSB, 1994, p. 47). According to Endsley's theory, these could be classified as Level 3 SA errors as the projection of future status would require operators to manage cockpit resources which clearly did not occur according to the NTSB.

While these types of SA errors may occur within dynamic environments, the operator in the loop may never suffer total loss of SA. However, one can determine whether one's or the team's SA is of high or low quality. SA of high quality would exist as the operational requirements of the definition of SA are maintained, i.e., perception, comprehension and projection of future dynamics. Similarly, low quality SA would exist when an error has occurred in any level of SA.

The Present Study

The purpose of this study is to test Endsley's model of SA through the analysis of incident report data. SA has been studied using a number of methods such as process indices (verbal protocols, process tracing), subjective assessment of SA (numerous scales exist), questionnaires (Endsley's Situation Awareness Global Assessment Technique), behavioral measures (i.e., communication frequency), and performance measures (Endsley, 1996). While these techniques exist, each only measures a portion of SA. Also, these differing methods of study also vary in their reliability and validity.

A recent call for study of the construct through the investigation of incident and accident report data was well received (Strauch, 1995). Strauch particularly praises the study of SA through the investigation of accident reports because of the logical progression and in-depth analysis investigators must use

in order to determine the causal factors affecting an accident, and to make future recommendations (Strauch, 1995).

Similarly, Chappell (1994) also calls for the study of constructs related to aviation psychology to use the wealth of incident report data which is part of the Aviation Safety Reporting System (ASRS). Chappell describes the database as a compendium of incident reports gathered from those who are involved with civil aviation throughout the United States. Persons submitting reports describe not only the factors involved with an incident, but in most cases how the incident occurred (refer to Appendix 1). It is important to note here that the ASRS database contains information on incidents, not accidents. Incident reports are gathered as crewmembers or air traffic controllers voluntarily submit reports in exchange for immunity regarding the actions that took place within an incident itself. While this form of data has its drawbacks (biases), it can be gathered in large numbers and has substantial ecological validity (Chappell, 1994).

To understand this type of research and how it relays valuable information to interested parties and the scientific community, consider a recent study by Owens and Sivak (1993). They used accident report data which is collected by the Fatal Accident Reporting System (FARS) in order to determine the role of reduced visibility in nighttime road fatalities. The researchers sampled a group of reports between the years of 1980 to 1990 and coded a number of variables, including the day of the week when the accident occurred,

weather and atmospheric conditions during the accident, and the lighting conditions under which it occurred. The results showed that a significant portion of the fatalities occurred during reduced lighting times of the day, thus showing that degraded visibility does indeed have an influence upon accidents and driving in general. The usefulness of this type of analysis using archival data is readily obvious.

The proposed research seeks to test Endsley's model of SA using voluntary incident report data. She states that the greatest number of SA errors will be in Level 2 of SA, information integration errors. In incident reports with poor SA, this translates into occurrences of poor information integration and comprehension. Based on Endsley's assertions, the first hypothesis is as follows:

H1: The most frequent occurrences of poor SA across all incident report data will involve Level 2 errors (comprehension and integration of perceived information).

While Endsley's theory says that most SA errors will occur in Level 2, comprehension, it seems that this finding is more appropriate for loss of an individual's SA. The discussion of team SA presented earlier, highlights the need for a shared understanding for good SA to exist. If teams must share information in order for high quality team SA to exist, it seems likely that Level 1 SA errors would occur at a higher proportion for teams. Thus, the next hypothesis to be proposed is as follows:

H2: A higher proportion of Level 1 SA errors will occur for team SA than for individual SA.

As it is hypothesized that team SA errors will include more Level 1 SA errors than for individual errors, it seems appropriate to investigate the possible factors in Endsley's model that might account for poor SA. For instance, research has shown that the process of communication is of the utmost importance in team decision-making. Studies by Orasanu (1990) and Mosier and Chidester (1991) have shown that without communication, the process of situation assessment, a precursor for SA, will breakdown. A team must perceive the information in order to begin developing SA, and when communication does not occur in a team, team SA should exist on an unacceptably poor level. It is possible that when poor team SA exists, within those instances that are categorized as Level 1 errors, communication will be the most frequent factor. A test of this assumption is stated as follows:

H3: Communication will be the most frequent factor affecting Level 1 SA errors when team SA is poor.

While communication is thought to be paramount, other factors also have an influence on SA. The environmental factors of workload and time pressure should also have a large impact upon SA in an aviation setting. While it is proposed in H3 that communication will predominate when team Level 1 SA errors occur, workload and time pressure should be the most frequent factors affecting Level 2 errors. This seems likely as both factors, workload and time pressure, induce stress upon operators, causing them to narrow their focus (as individuals or in teams), leading the operators to make premature decisions. As

stated earlier, as attentional demands are increased and working memory is constrained by stress from workload and time pressure, one is limited in one's abilities to retrieve and utilize the information stored in long-term memory. Thus, this induced stress from workload and time pressure should limit one's ability to comprehend and integrate all of the information surrounding him or her. The final hypothesis to be tested by this research is as follows:

H4: Workload and time pressure will be the most frequently occurring factors affecting Level 2 SA errors.

CHAPTER II

METHOD

Materials

Five hundred-ninety ASRS incident reports were used as the primary data source for this research. An example of this report form is provided as Appendix A. The reports used for this study were gathered by requesting the most recent set of 600 incident reports that ASRS could provide. A representative sample of 590 reports were gathered from the time period of November 1995 through March 1996 and sent to the researcher for analysis.

Design

A 2 x 3 quasi-experimental design was used. The two classification variables of the study are the type of SA (individual or team), and the level of SA error (Level 1, 2, or 3). The behavioral variables were the presence of workload (high vs. low), time pressure (high vs. low), and the quality of communication (poor vs. good) on the flight deck. Operational definitions of these classification and behavioral variables are shown in the scoring protocol (Appendix B).

Procedure (Assessment of the Reports)

Each ASRS incident report was analyzed using the scoring protocol shown in Appendix B. Information from each report was gathered concerning a determination if poor SA quality existed, and if so, the level of SA error, and whether the incident involved team or individual SA. Also information concerning the possible explanatory factors affecting the incident including instances of weather problems, equipment problems, distractions, improper procedures, unfamiliarity with the airframe or area of flight, night conditions, fatigue, emotional crew members, communication, workload, and time pressure were gathered from each report. Finally, information concerning the phase of flight when the incident occurred was recorded.

The researcher read each report and followed the detailed description for scoring the reports as described in the protocol. A database of information was compiled for SA errors and portions of it are presented in Appendix C.

Reliability of Coding Scheme

Test-retest and inter-rater forms of reliability were pertinent to the analysis of the incident report data. Subjective assessments of the incident reports occurred when determining if a loss in SA occurred, who was involved with that loss (individual or entire crew), the phase of flight in which the incident occurred, and the factors which existed during the incident. The test-retest reliability coefficients ranged from of 0.816 (Workload factor) to 0.517 (other factors involved) with an overall coefficient of 0.718. The inter-rater reliability

check was completed by having three raters (the researcher, a US Air Force pilot, and a General Aviation pilot) complete two samples of 22 reports each (all 44 from the total sample population of the 590 reports) in order to assess the levels of agreement across the variables of consideration. The researcher is a US Air Force behavioral scientist with no flight experience. Another rater is a Certified Flight Instructor with a single engine rating and 300 total hours of flight time. The other rater is a US Air Force KC-135 Command Pilot with 2500 flight hours occupying crew positions of command pilot, copilot, and flight instructor. The inter-rater reliability coefficients ranged from 0.794 (Workload factor) to 0.404 (level of SA error) with an overall inter-rater reliability of 0.609. All reliability coefficients are shown in Table I. While these levels of vary, these raters did not go through extensive training in scoring. Instead they read and scored the reports using the standardized protocol as presented. Thus, training would likely increase these reliability coefficients.

While these reliability coefficients may be considered "low" in some instances, they do point out that a number of the decisions raters had to make concerning the variables of interest were quite difficult. This information can be useful for other researchers when either revising or replicating this form of research as they can better understand which aspects of protocol development may need more attention than others.

It is also interesting to note the lower reliability coefficients regarding CFI with the other raters from Table I. As this rater works a great distance from the primary researcher, time could not be spent discussing a large number of the ratings given for variables within each of the sets of reports used for reliability purposes. It is likely that if each of the researchers would have had more access to each other to discuss the ratings given during each reliability set, susequent ratings would have shown higher agreement levels.

Table I. Test-retest and inter-rater reliability coefficients.

	Reliability				
Variables	RE-AFP	RE-CFI	CFI-AFP	Inter-rater	Test-Retest
SA Error	.896	.542	.458	.632	.896
Level of SA	.644	.339	.230	.404	.605
Who involved Incident	.864	.659	.523	.682	.864
Communication	.725	.589	.639	.651	.817
Other Factors	.517	.332	.389	.412	.517
Workload	.897	.795	.690	.794	.897
Time Pressure	.897	.727	.690	.771	.795
Phase of Flight	.661	.444	.467	.524	.596
	Overall Average reliability			.609	.748

RE=Researcher

AFP=Air Force Pilot Rater

CFI=Certified Flight Instructor Rater

CHAPTER III

RESULTS

Descriptive statistics were gathered from the 590 incident reports. Tables were developed to show both the relative frequency of the different levels of SA involved in the incidents, and also the major trends within the data concerning the factors involved when SA errors did and did not occur. The data concerning the level SA errors was coded using a 1-to-5 scale which allowed coders to rate the extent to which any level of SA error existed. Any error rated 5 was considered to be an error involving that level of SA. Table II shows the distribution of ratings.

Based upon the transformations of the data from the rating scales, it was determined that 239 incidents did not involve any SA error (no SA rating of 5) , 205 incidents involved some level of SA error (at least one SA rating of 5), and 146 incidents involved bad information or no information being passed to the pilots, crews, or ATC controllers involved. For these last incidents, no SA error rating was assigned.

Table III lists the factors which affected incidents when no SA error occurred, when an SA error was identified, and when poor information was given to operators or information was not available. The instances of poor information being given to a crew member or when information was not

available were not considered instances of SA errors. Endsley's theory (1995a) would categorize these instances as Level 1 SA errors, but within the scope of this research, they were not considered SA errors because pilots, crews, or ATC operators would not have had the opportunity to develop a good perception and understanding of the current situation. The distinction was made between controllable SA errors and instances where poor or no information was provided to the pilot, crew, or ATC operator. Table III compares factors affecting incidents that did not involve SA with those involving poor or no information being available, and incidents when an SA

Table II. Frequency of incidents being rated for SA errors using the study protocol. Each incident was rated on every level of SA.

Scale used: error absolutely does not fall into this level category 1 2 3 4 5 error absolutely falls into this level category

	Rating Received				
Level of SA	1	2	3	4	5
1	455	17	18	5	95
2	468	10	20	7	85
3	550	5	8	1	26

error occurred. Tables IV compares these groups in terms of phase of flight when the incidents occurred.

Based upon an examination of these two tables, it can be seen that extracting the incidents which involved poor information were similar to those of no SA error. The factors affecting these incidents as well as the incidents involving no SA error are very similar (except for poor communication, which is what defined the second group). As shown in Table IV, the SA group is different from the others in terms of the phase of flight of the incident. Therefore, the incidents involving no SA loss and poor or no information were combined (as a conservative test of SA) for a total of 385 incidents for the remainder of the analyses performed.

Table III. Percentage of reports with contributing factors identified.

	No SA Error	Bad Information Given	SA Error
N	239	146	205
Factors			
Poor Communication	5.0	36.3	29.7
High Workload	3.8	5.4	16.6
High Time Pressure	16.0	22.6	23.4
Weather	26.1	21.2	32.2
Improper Procedure	17.3	19.2	44.4
Unfamiliarity	1.7	2.7	21.0
Night Conditions	4.2	7.5	20.0
Distractions	5.5	8.9	20.0
Equipment Problems	31.9	43.2	10.2
Fatigue	0.4	0.0	7.3
Emotions	1.3	0.0	1.4

Table IV. Percent of incidents by phase of flight.

	No SA Error	Bad Information Given	SA Error
N	238	146	205
Phase of Flight			
Preflight	7.6	9.6	8.3
Taxi-out	6.7	3.4	21.0
Takeoff	7.6	8.90	3.4
Climb	6.7	9.6	7.8
Cruise	18.5	24.0	8.5
Descent	5.5	6.9	8.3
Approach	17.6	17.1	16.1
Landing	7.1	2.7	4.4
Taxi-in	4.6	1.4	8.8
Unable to Determine	16.8	15.8	3.4

The following sections examine the four hypotheses of this study and the additional analyses which were performed. The additional analyses address the contributing factors that affected incidents as well as the phase of flight in which incidents and SA errors occurred. Some of the tests for both the hypotheses and

addtional analyses of contributing factors and the phase of flight were base on two series of Multivariate Analyses of Variance (MANOVA).

One series of MANOVAs examined the pattern of factors affecting team SA errors, individual SA errors, and incidents when no SA errors occurred. A MANOVA was conducted for each level of SA. The independent grouping variable was based on team SA errors, individual SA errors, and incidents involving no SA error. The 11 dependent variables were the factors shown in Table III. A Bonferroni significance level correction was performed for the three MANOVAs. The first MANOVA testing for differences between the groups for Level 1 SA was significant, $\underline{F}$ (22, 908) = 6.982, $\underline{p}<0.016$, $\underline{R}^2 = 0.247$. (Throughout this study, findings are considered significant when $\underline{p}<0.05$ unless more conservative post hoc significance level adjustments were necessary). The second MANOVA testing for differences between the grouping variables for Level 2 SA was also found to be significant, $\underline{F}$ (22, 908)= 9.995, $\underline{R}^2 = 0.311$, as was the third MANOVA for Level 3, $\underline{F}$ (22, 790) = 6.355, $\underline{R}^2 = .222$.

The second series of MANOVAs was based on differences in phases of flight among the three groups. The 10 dependent variables were the different phases of flight shown in Table IV. A MANOVA test was conducted for each level of SA and, again, Bonferroni significance level corrections were performed. Two of the three MANOVAs were significant; for Level 1 SA, $\underline{F}$(18, 932) = 3.280, $\underline{R}^2 = 0.106$; and for Level 2 SA, $\underline{F}$ (18, 912) = 4.07, $\underline{R}^2 = 0.125$. The MANOVA for Level 3 SA errors was not significant, $\underline{F}$ (18, 794) = 1.57, $\underline{R}^2 = 0.054$.

When significant differences were found in the MANOVAs, individual Analysis of Variance (ANOVA) tests were performed on the factors or phases of flight.

Tests of Hypotheses

The first hypothesis predicted that the most frequent occurrences of poor SA would involve Level 2 SA errors. Table V shows the number of errors which occurred by Level of SA. A Chi-square test for goodness of fit test showed that a significant difference exists between the frequency of these types of errors , χ^2 (2) = 42.08. The significant difference results from the fewer number of Level 3 SA errors. Level 2 SA errors did not occur most often. Thus, the first hypothesis was not supported.

The second hypothesis predicted that when team SA could be differentiated from individual SA, a higher proportion of Level 1 errors would exist for teams. The first row of Table VI lists the frequency of SA errors by level for teams and individuals. A Chi-square for independence test was performed to determine if these frequencies were significantly different. It was found that they were not significantly different, χ^2 (2) = 1.18. The second hypothesis was not supported, as 47% of the individual errors involved Level 1 SA and 45% of the team errors involved Level 1 SA.

Table V. Frequency of SA errors by level.

Levels of SA Error	Frequency	Percentage of Errors
1	95	46.1%
2	85	41.3%
3	26	12.6%
1 and 2	1	0.5%
1 and 3	0	0.0%
2 and 3	0	0.0%
1, 2 and 3	0	0.0%

Level 1 SA Error: Failure to perceive available information

Level 2 SA Error: Failure to comprehend or integrate perceived information

Level 3 SA Error: Failure to predict the near future status of current dynamics based upon information comprehended

Table VI. Percent frequency of individual and team errors by SA level.

		Individual			Team		
	No SA Error	L 1	L 2	L 3	L 1	L 2	L 3
N	385	48	39	15	47	46	11
Factors							
Poor Communication	16.9	16.7	30.8	20.0	23.4	47.8	45.5
High Workload	4.4	10.4	17.9	6.7	14.9	23.9	27.3
High Time Pressure	18.3	22.9	28.2	40.0	14.9	17.4	45.5
Weather	24.1	29.2	35.9	33.3	38.3	26.1	27.3
Improper Procedure	18.1	42.0	53.8	46.6	34.0	34.8	100.0
Distractions	6.8	22.9	20.5	13.3	29.8	13.0	9.1
Night Conditions	5.2	27.1	17.9	20.0	19.1	17.4	9.1
Unfamiliarity	2.1	12.5	35.9	26.6	10.6	26.1	18.2
Equipment Problems	36.1	10.4	17.9	6.7	10.6	2.2	18.2
Fatigue	0.3	10.4	5.1	0.0	10.6	4.3	9.1
Emotions	0.3	2.1	2.6	6.7	0.0	0.0	0.0

The third hypothesis predicted that the most frequent factor affecting Level 1 SA errors for teams would be poor communication. In order to answer this question, an ANOVA was performed for Level 1 SA errors which showed

that poor communication was not significantly different, $\underline{F}$ (2, 474) = 0.65, $\underline{R}^2$ = 0.002. Table VI shows the percent frequency of poor communication for team Level 1 SA errors, individual Level 1 SA errors and incidents involving no SA errors. While poor communication affects 23.4% of the team Level 1 SA errors it is not significantly different from the individual Level 1 SA errors or the no SA errors groups. The hypothesis that communication difficulties would be the most frequent factor affecting team Level 1 SA errors is not supported.

The final hypothesis stated that the most frequent factors affecting Level 2 SA errors for teams would be workload and time pressure. Analysis of the individual ANOVA tests showed that high workload was significantly different among groups $\underline{F}$ (2, 464) = 15.44, $\underline{R}^2$ = 0.062. Tukey HSD calculations showed that it significantly affected a larger proportion of team Level 2 SA errors than incidents which did not involve SA errors. However, team and individual Level 2 SA errors were not different.

High time pressure was not found to be a significant factor affecting team Level 2 SA errors, individual Level 2 SA errors, and incidents involving no SA errors, $\underline{F}$ (2, 464) = 1.16, $\underline{R}^2$ = 0.005. In Table V, one can see that while workload and time pressure occur in 41.3% of the Level 2 team SA, they are not the most frequently occurring factors. The most frequently occurring factor for team Level 2 SA errors was poor communication (47.8%). Thus, the final hypothesis was only partially supported.

Additional Analyses

As discussed previously, poor communication accounted for a significantly larger proportion of errors involving team Level 2 SA. Additional tests were performed to better understand what could have led to this result. Instances of poor communication had been coded as involving just the crew members of an aircraft or involving crew members and outside sources such as air traffic control (ATC). An analysis of the data showed that only 3 (of the 22 total) instances of poor communication within team Level 2 SA errors involved only crew members. The other 19 instances involved poor communication between crew members and other sources of communication and information such as ATC. A Chi-square test for goodness of fit shows that this difference in instances of poor communication was significant, χ^2 (1) = 10.36.

In order to understand the if other possible factors beside communication, high workload, and high time pressure differentially affected team Level 1 SA errors, individual Level 1 SA errors and incidents involving no SA errors, individual ANOVA tests were performed. The factors of improper procedures [F (2, 474) = 9.42, R^2 = 0.038], distractions [F (2, 474) = 16.76, R^2 = 0. 066], night time conditions [F (2, 474) = 17.21, R^2 = 0.068], level of familiarity [F (2, 474) = 9.35, R^2 = 0.038] equipment problems [F (2, 474) = 12.17, R^2 = 0.049], and fatigue [F (2, 474) = 19.11, R^2 = 0.075] were significant for Level 1 SA errors. Tukey HSD calculations were performed to identify differences among the grouping variables when significant differences were found. The pattern that emerges is

that for both team and individual Level 1 SA errors, each of these contributing factors except for equipment problems occur in significantly higher proportions than in incidents involving no SA error. Equipment problems occurred in significantly higher proportions of incidents involving no SA error.

The same set of ANOVA tests were performed for Level 2 SA errors. Improper procedures [F (2, 464) = 15.97, R^2 = 0.064], poor communication [F (2, 464) = 13.88, R^2 = 0.056, distractions [F (2, 464) =4.93, R^2 = 0.021], night time conditions [F (2, 464) = 7.94, R^2 = 0.033], familiarity [F (2, 464) = 52.84, R^2 = 0.185], equipment problems [F (2, 464) = 13.42, R^2 = 0.055], and fatigue [F (2, 464) = 6.69, R^2 = 0.028] were all found to produce significant group differences. Tukey HSD calculations were performed to identify differences among the grouping variables when significant differences were found. Poor communication was found significantly more often in team errors than individual or no Level 2 SA errors. The factors of improper procedures and distractions occurred in only a significantly higher proportion of individual Level 2 SA errors compared to the other two groups. The factors of night conditions, familiarity, and fatigue occurred in significantly higher proportions of both team and individual Level 2 SA errors than in the no SA error group.

Finally, individual ANOVA tests were performed to find the factors which differentially affected Level 3 SA errors. The results show that the factors of improper procedure [F (2, 405) = 27.48, R^2 = 0.119], poor communication [F (2, 405) = 3.08, R^2 = 0.15], familiarity [F (2, 405) = 18.25, R^2 = 0.083], high workload [F

(2, 405) = 5.86, $\underline{R}^2$ = 0.028], high time pressure [$\underline{F}$ (2, 405) = 4.53, $\underline{R}^2$ = 0.022], equipment problems [$\underline{F}$ (2, 405) = 3.47, $\underline{R}^2$ = 0.017], and fatigue [$\underline{F}$ (2, 405) = 8.89, $\underline{R}^2$ = 0.042] were all found to be significantly different depending on whether they occurred in a team SA error, an individual SA error or an incident involving no SA error. Tukey HSD tests showed that the factors of improper procedures, poor communication, high workload, and fatigue all occurred in significantly higher proportions for team Level 3 SA errors compared to the other two groups. The factors of familiarity and high time pressure occurred in significantly higher proportions of both team and individual Level 3 SA errors.

In summary, only one factor, level of familiarity, was consistently found more in SA error groups than the no SA error group across all three levels of SA error for both teams and individuals. Two factors (night conditions and fatigue) occur consistently more often in both team and individual Level 1 and 2 SA errors. The other factors of improper procedures, distractions, high workload, poor communication, and high time pressure seem to affect only certain levels of SA for teams or individuals.

In order to understand the phase of flight when the different types of SA errors occurred, individual ANOVA tests were performed. Table VII shows the percent frequency of errors and incidents during each phase of flight for team, individuals and incidents involving no SA errors. The series of ANOVA tests for phase of flight for Level 1 SA error showed differences only for taxi-out [$\underline{F}$ (2, 474) = 13.56, $\underline{R}^2$ = 0.054] and taxi-in [$\underline{F}$ (2, 474) = 7.06, $\underline{R}^2$ = 0.029]. The Tukey HSD

tests revealed that taxi-in was cited more frequently for individual SA errors than the other two groups and taxi-out was cited more frequently for team SA errors than the other two groups.

Table VII. Percent of incidents by SA level, origin of error, and phase of flight.

		Individual			Team		
	No SA Error	L 1	L 2	L3	L 1	L 2	L 3
N	385	48	39	15	47	46	11
Phase of Flight							
Preflight	8.3	10.4	5.1	20.0	12.5	2.1	0.0
Taxi-out	6.2	16.7	15.4	6.7	25.5	34.8	0.0
Takeoff	8.1	2.1	2.6	0.0	6.4	4.3	0.0
Climb	7.8	6.3	12.8	20.0	4.3	2.2	18.2
Cruise	20.3	18.8	30.8	13.3	14.9	17.4	9.1
Descent	6.0	8.3	5.1	0.0	10.6	13.0	0.0
Approach	17.4	8.3	15.4	20.0	12.8	17.4	54.5
Landing	5.2	4.2	7.7	13.3	2.1	0.0	9.1
Taxi-in	3.4	14.6	2.6	6.7	10.6	6.5	9.1
Unable to Determine	17.4	8.3	2.6	0.0	0.0	2.2	0.0

The set of ANOVA tests for Level 2 SA errors for phase of flight showed that significant differences during the taxi-out phase of flight [F (2, 464) = 24.17,

$R^2 = 0.094$]. Tukey HSD calculations found that a significantly higher proportion of team Level 2 SA errors than the two other groups occurred during taxi-out than in the other groups.

CHAPTER IV

DISCUSSION

Based on the results of this study, there are several findings meriting further discussion from a theoretical and practical standpoint. The support for the hypotheses will be presented and discussed as well as the implications for Endsley's (1995a) theory. Based on the analysis of factors related to team and individual SA new models will be presented for both team and individual SA. Finally, conclusions and recommendations will be presented regarding research using incident reports and future research should concerning SA.

Evaluation of Hypotheses

The first hypothesis that Level 2 SA errors would be the most frequent types of SA errors made by operators was not supported by this research. Instead, it was found that Level 1 SA errors, perception failures (failure to perceive available information important to task, person recognizes error as it occurs), occurred slightly more frequently. While there was not a significant difference between the number of Level 1 and Level 2 SA errors, these findings present a somewhat different picture than what the literature surrounding SA depicts (Endsley, 1995a). While errors involving the comprehension of available information do happen frequently, as these results suggest, it seems that the outside influence of environmental factors such as high workload, distractions, night conditions, fatigue, weather, and unfamiliarity with the airframe or area have a large impact upon the ability of aviators to correctly perceive information.

While Endsley (1995a) acknowledges that attention is limited and a myriad of outside factors which can affect one's ability to correctly perceive available information abound, this may be more of a problem than first expected. Within her discussion of the factors which affect Level 1 SA errors, she mentions that "some people appear to be better than others at dividing their attention across different tasks" (Endsley, 1995a, p. 55). This statement has specific relevance in light of results found as numerous factors are working against aviators as they seek to divide their attention across tasks. From a practical view, these results present a need for developing more specific training strategies in helping aviators manage SA at its basic level, dividing one's attention in order perceive needed information. From a theoretical standpoint, the finding that Level 2 SA errors are not the most frequent SA errors means that more focus should be given to the loss of perception when modeling SA errors.

Proctor and Van Zandt (1994) describe a number of strategies which are advocated when trying to help train operators in increasing there abilities for divided attention. First, these researchers state that operators must be given ample practice in dividing their attention across modalities during simulation tasks. This practice in dividing one's attention across modalities should help to operators become more proficient at obtaining as well as understanding information in dynamic environments. Further, these researchers state that operators should be given training in priortizing and planning for divided attention. Here, the researchers advocate helping operators develop an action plan for dealing with information when that information comes from various sources. Finally, Proctor and Van Zandt support delegating duties between operators so that a smaller, more defined amount of information is attended to by each operator.

The second hypothesis stated that for teams, a higher number of Level 1 SA errors would exist. This hypothesis was not supported by this research. Instead, it was found that for teams, the number of errors were fairly evenly distributed between Level 1 and 2 SA errors, while Level 3 SA errors occurred least often. This results parallels the findings from the previous hypothesis. This pattern seems to show that for team SA, both perception of environmental information and comprehension of that information are equally important problems. It was thought that team SA would only exist if team members shared information between themselves, thus leading to a higher proportion of perception problems. What this result indicates is that teams have equal problems in both perceiving or sharing information and in building a team shared mental model.

The recent research by Salas et al., (1995) elaborates on the importance of the team shared mental model for good team SA. Clearly the viewpoint provided by these researchers hinges on the notion of sharing the information perceived and working to understand that information as a team. Salas et al., (1995) report that training for team SA should encompass both critical information-seeking behavior for teams and training on team competencies for crews which rotate members regularly. Both of these recommendations are supported by this research because teams have equal difficulty both in gathering and also comprehending the information needed for good decision-making.

The third hypothesis stated that poor communication would be the most frequent factor affecting team Level 1 SA. This hypothesis followed from the second hypothesis. It was thought that team Level 1 SA would require good communication before good team perception of the current situation would exist. While the data from this study do not support this hypothesis entirely, it does support the importance of good communication for team perceptions. Poor

communication was found to be a contributing factor in 23.4% of team Level 1 SA errors. Thus, it occurs in a fairly large number of incidents involving team Level 1 SA errors.

While poor communication was not found to be the most frequent factor affecting team Level 1 SA, it was found to be the most frequent factor affecting team Level 2 SA, comprehension of information. Aviation crews are forced to understand a great deal of information pertaining to changing weather conditions, the status of aircraft around them, as well as any and all information pertaining to their current heading, speed, and altitude. It seems plausible that good communication would be necessary for sufficient *understanding* of a developing situation. Those crews which have spent many hours flying together on numerous occasions may develop a shared mental model based on reading instruments alone without requiring overt verbal communication. This finding that poor communication is such a large factor affecting team Level 2 SA supports the current research which is being conducted on improving crew communication for developing that shared problem model of a developing situation (Salas et al., 1995). By focusing efforts on understanding team communication processes, we can develop stronger training programs to support team comprehension of problem situations.

The final hypothesis of this study stated that high workload and time pressure would be the most frequent factors affecting team Level 2 SA. The results showed partial support for this hypothesis. High workload was found to be a significant factor affecting team Level 2 SA (occurring in 23.9% of team Level 2 SA errors). Since high workload was found be to a significant factor affecting team Level 2 SA, support is given to the model presented by Endsley (1996) where she describes how poor SA and high workload often occur simultaneously. She describes that as the information and demand of tasks

becomes too great, the operator begins to lose the ability to integrate all of the available information (Endsley, 1996). This view is supported by the present research.

While high workload was found to be a significant factor affecting team Level 2 SA, the same finding was not true for high time pressure. While high time pressure was found to be a contributing factor in 17.4% of the team Level 2 SA errors, this trend is not different from the amount of incidents without SA errors. High time pressure seemed to exist across many of the 590 incident reports. It seems that the general level of high time pressure for most aviation incidents masks its significance for team SA. This is a potentially interesting finding because previous research into the factors affecting aviation accidents does not mention the factor of time pressure (NTSB, 1994). If high time pressure remains fairly constant across SA errors and more general incidents alike, it seems to be an organizational issue which must be addressed. Aviation administrative bodies should investigate methods for reducing time pressure within the aviation environment.

Evaluation of Additional Analyses

While the thrust of this research centered around the main hypotheses discussed above, additional analyses were performed in order to understand more about the nature of SA errors. Much of these findings will be discussed in a later section of the discussion where new models of SA errors are presented. What follows is a discussion of the phase of flight when SA errors occur, and a discussion of other findings concerning poor communication.

It was found that a significantly higher proportion of team Level 1 and 2 SA errors occurred during taxi-out. During this particular phase of flight, crews are performing numerous last minute checklist procedures, communicating with

ATC and ground control, as well as maneuvering the aircraft for positioning for takeoff. This is a very busy phase of flight and the increased workload could be seen as a possible causal factor. However, it also found that poor communication occurred in a significantly higher proportion of team Level 2 SA errors and most of those poor communication interactions took place between crews and ATC. It seems very possible that the poor communication that was occurring between crews and ATC was a main determinant of the subsequent SA loss among crews.

Looking back to the individual ASRS reports in question when poor communication between crews and ATC occurred, it was found that many instances of missing "hold short lines" occurred. These are stopping areas placed just outside of active taxiways so that aircraft do not conflict with each other. This could mean that ATC personnel and crews are not sharing the same mental model or understanding of where those hold short lines are and where the crews should be holding. This particular example shows how critical explicit communication is for the accomplishment of airline operations. Possible solutions to this problem do exist. Since there is some discrepancy in the terminology used to tell crews where they should be holding, a simple solution would be for this terminology to be standardized industry wide.

Implications for Endsley's Theory

This research relied on Endsley's (1995a) theory of SA. First, this theory has been shown to be extremely useful in shaping a measurement instrument for gather information about SA loss from incident report data. The definitions and model presented by Endsley's (1995a) theory have been clear enough to use when scoring a variety of narrative reports. The theory also allows for an interpretation of the subsequent data.

Second, Endsley's model, this researcher developed very specific definitions of Level 1, 2, and 3 SA errors as well as relating how numerous factors affect those errors for both teams and individuals. Endsley (1995a) does a very good job of describing SA errors across the specific levels of SA. These definitions and examples served as the main guidelines for the incident scoring protocol used in this study. Thus, the theory presents very useful concrete examples of what an incident would contain when SA is poor.

Third, Endsley's theory is extremely useful from a researcher's point of view, it does have some shortcomings when being used to evaluate SA error or loss. This theory does not describe at great lengths the subtle differences which exist between team and individual SA loss. Instead, the theory gives general descriptions of the requirements for team SA ("degree to which every team member possesses the SA required for his/her responsibilities", Endsley, 1995a, p. 39) and descriptions of the nature of Level 1, 2 and 3 SA errors. This theory, however, does a somewhat poor job of describing the absolute importance of good communication for the development of team SA within its higher levels.

Endsley describes that good communication may or may not be needed for good Level 2 and 3 SA as shared mental models and scanning strategies may circumvent the need for explicit communication (Endsley, 1995a). She also cites work that has shown that more efficient communication is a real key for good team SA in the higher levels (Endsley, 1995a). What this research has shown is that without explicit communication between crew members and those outside the flight deck (ATC), poor team SA is very likely to exist. Since 47.8% and 45.5% of the team Level 2 and 3 SA errors, respectively, involve poor communication, the theory must underscore and specifically list the factor of communication as a moderating variable for the development of team SA.

New Models of Individual and Team SA Loss

Since Endsley's theory gives only models of the components of SA and lists only some of the factors which may have an impact upon, new models of both individual and team SA loss should be developed. The present research allows for the development of such models because it provides data concerning the relative proportions of external factors affecting poor SA for both individuals and teams. The development of these models does not detract from those which have already been published. Instead, it adds to the knowledge base surrounding poor SA.

Figure 2 presents the differences in the factors which affect incidents involving no SA error and factors affecting incidents involving SA errors. This figure shows the impact of external factors upon SA errors. While the incident report data studied does not allow a researcher to understand the effects of one's abilities, training, experience upon SA errors, it does allow one to understand the factors which affect higher proportions of SA loss incidents than incidents involving no SA error. One can see that many more factors come into play when SA is considered to be poor. While this research focused upon the relative impact of three of these factors upon SA (poor communication, high workload, and high time pressure), it is very evident that at least six other factors are working against aviation personnel in the fight to maintain peak SA. With this information and the finding that 205 of 590 incidents involved SA at some level, one can see that SA must receive continued attention from both a research (theory) and organizational (practical) standpoint.

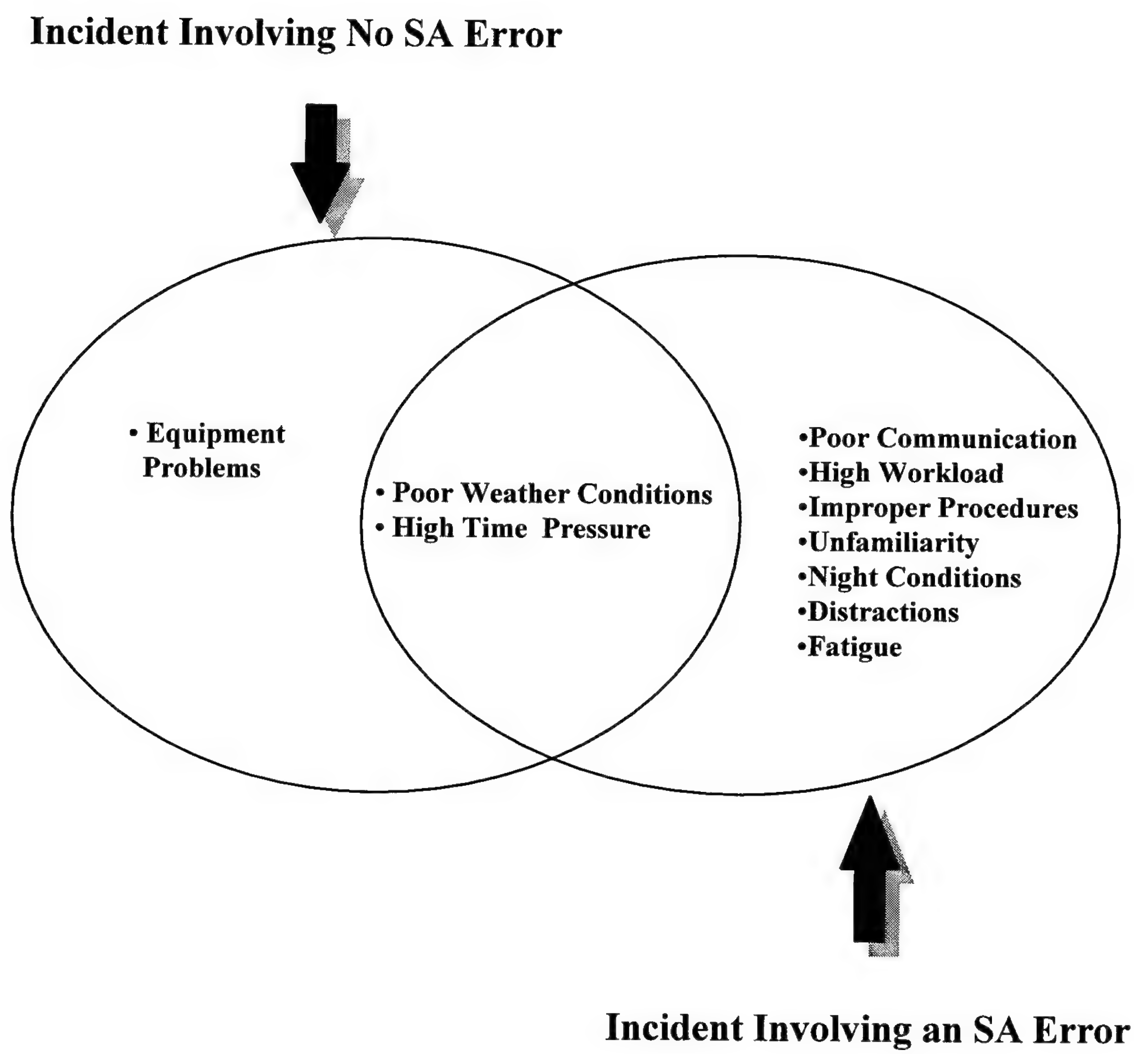

Figure 2. Differences in factors affecting SA error incidents and incidents involving no SA error.

Figure 3 presents the factors which were found to have a large effect upon poor individual SA at all three levels. It is important to note that common factors occur within all three levels of individual SA loss. The factors of performing improper procedures and unfamiliarity (with the airframe or systems being used, other crew members, or a geographical area) seem to affect almost all three levels of individual SA. This is not the first occurrence of these factors having a large effect upon aircraft incidents and accidents. The NTSB (1994) found that in the 37 fatal accidents occurring between 1987 and 1990, 24.2% of the errors involved in these accidents involved improper procedures, while 73% of the accidents (in which information was available) involved unfamiliarity of the crew members. With this information, it is imperative that aviation management truly focus upon both the training procedures used in aviation and the practices with which it assigns personnel to flights.

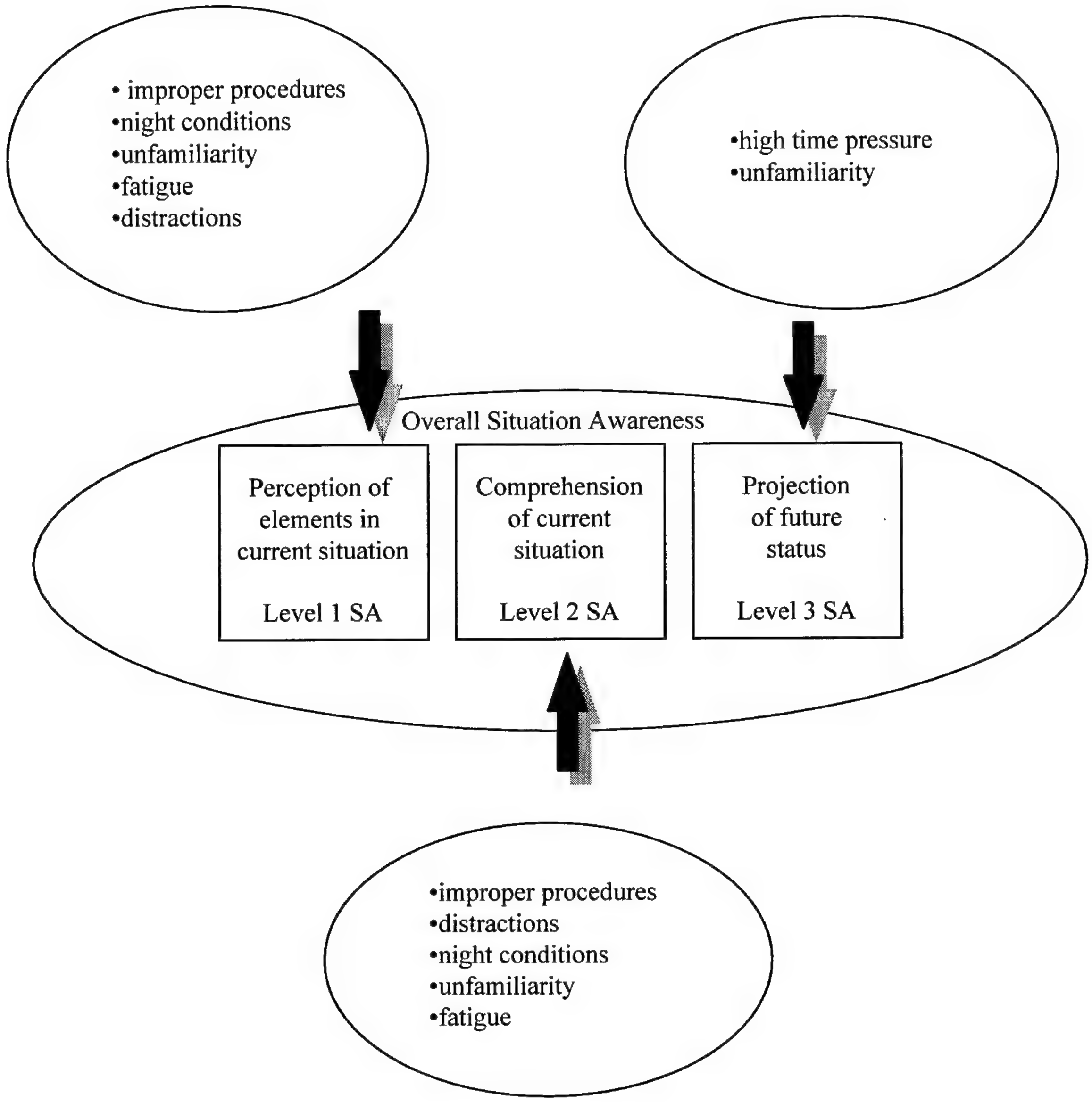

Figure 3. A model of individual SA errors.

While Figure 3 presented a model of poor individual SA, Figure 4 paints a somewhat different picture of the factors which affect poor team SA. This model shows that the additional factors of high workload, poor communication, high time pressure, and fatigue seem to affect poor SA when a team is involved. This finding is not particularly surprising in the light of past research. Aviation

research into the factors associated with human error have traditionally considered these factors to be important for study and understanding.

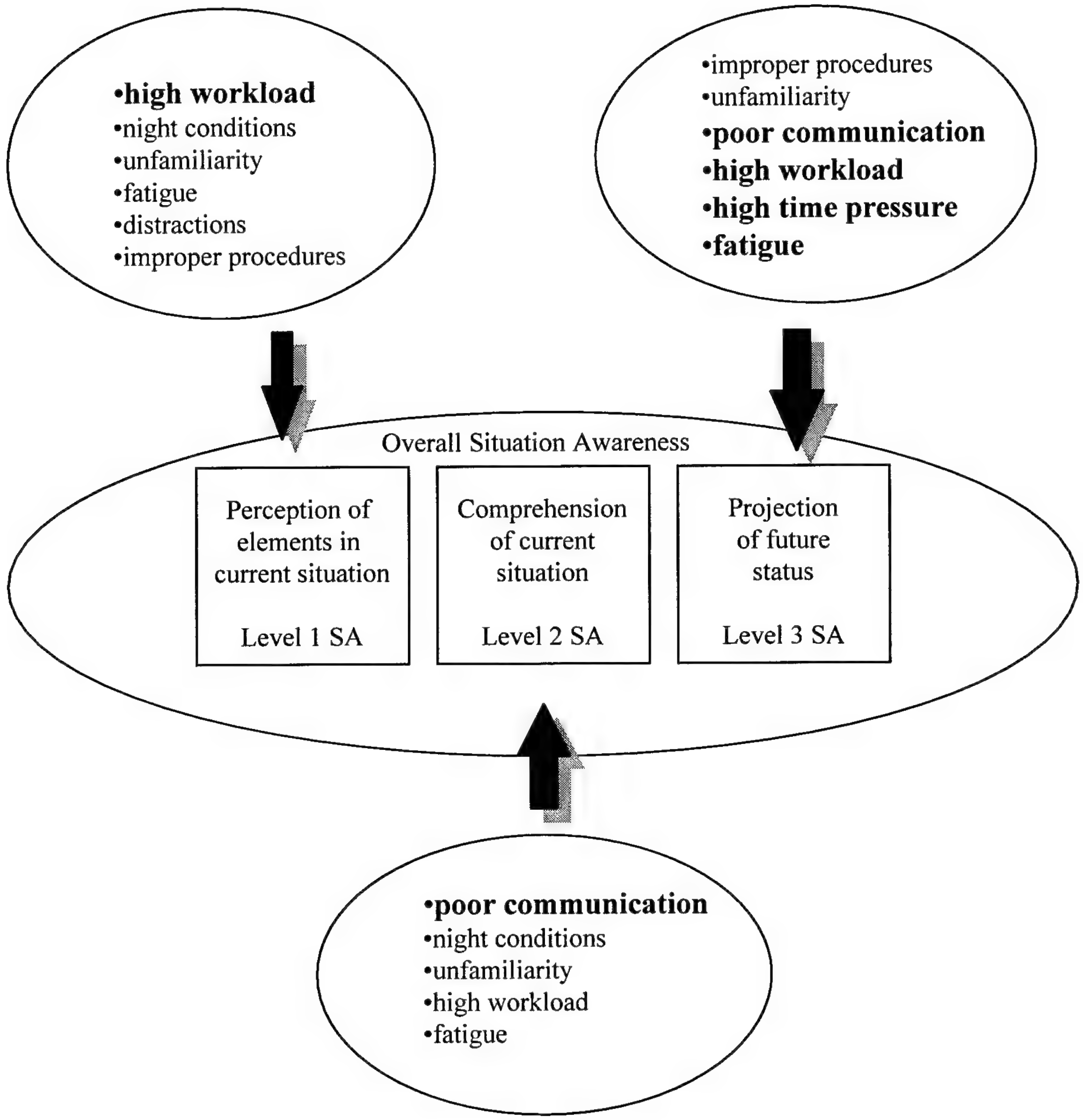

Figure 4. A model of team SA errors.

What is surprising is that these factors differentially affect SA when the SA loss involves the complex interactions of teams or crews. Because good team work is necessary within the aviation environment as well as most other work

environments, it is important to focus upon training strategies that will work to help the team deal with these factors. Such strategies could include the development of shared mental model training to help teams deal with the pressures of high-workload situations when they are compounded by time pressure. By lessening the cognitive burdens on the operators, teams can focus upon their shared understanding of the situation, and less upon trying to determine what the other team members believe is occurring. Teams can also work on efficient communication strategies (using clear language, only stating necessary and important information, and providing the information in a timely fashion) for producing necessary information among team members before it becomes an essential commodity. Finally, in order to address fatigue, administrators must work to help develop more worker-centered schedules for aviators and other types of employees supplemented with regular rest periods.

Value of Incident Report Data

The research conducted here has outlined the usefulness of incident report data. With all of its drawbacks considered (reporter biases, lack of causality from archival data, and skewed distributions of reports), the incidents analyzed have provided a wealth of information regarding poor SA, when it occurs, the factors involved, and how we can work to address these issues. This type of data is readily available and can be solicited in mass quantities. It is as an extremely useful source of information when trying to understand the factors which aviators, air traffic controllers, ground personnel, mechanics, dispatchers, and other personnel feel effect a loss of SA.

While this type of data is extremely useful, it does have some drawbacks. One of the most important drawbacks to consider is the fact that this data can be presented to a reader in any number of forms. This means that the reporters will

give the information they feel is important using their own personal communication skills. This often leads to a wide variety of possibilities of interpretations of the data as standardization is lost. For example, it was surprising to find the low inter-rater agreement when trying to determine the phase of flight in which an incident occurred. Each of the raters insisted that this should have been an easy goal to achieve. However, because the incident reports can be presented in basically any form of narrative style , it was difficult, for example, to determine if the reporter was describing the beginning of an approach or simply a descent when configuring the aircraft just prior to final approach. Incident report data can vary in describing a situation or phase of flight and it becomes very difficult to standardize a scoring protocol to analyze this type of data.

One other drawback to this type of data is that it becomes very difficult to understand the higher level cognitive states of operators based on their verbal representation of a given incident. This fact could have affected the results of this study because it was difficult to identify if a Level 3 SA error had occurred unless the reporter could clearly define the thought processes in the incident report itself. It is entirely possible that more Level 3 SA errors are occurring in civilian aviation not simply because they are not reported, but because the language of the reports does not allow the easy identification of a Level 3 SA. Because these reports are based on the thoughts of aviation personnel, the drawbacks of a narrative format could be masking the existence of certain types of errors.

Conclusions and Recommendations

There are two readily evident conclusions which can be drawn from this research. First, SA is a real factor affecting the everyday activities of civilian

aviation. This is seen through both the sheer number of reports involving SA errors as reported by actual aviation personnel and findings that show SA errors involve different factors from incidents not involving SA errors. Both laboratory and field research should continue to better understand this construct and how human factors engineering and training can be used to support SA.

A second conclusion is that the theory of SA developed by Endsley (1995a) has ecological validity and is very useful in capturing SA errors. While this theory may need some refining, it does describe the critical components of SA or how errors involving SA may look. Using the information from this study and others, the theory should continue to be improved for practical use within not only aviation, but other fields.

While the factors of poor communication, high workload and high time pressure were the primary factors of this research, considerable amounts of information have been gained concerning the impact of other factors affecting SA errors. It was found that these factors have differential effects upon SA in its different levels for both teams and individuals. This information should be examined and used further because it is based on direct reports of incidents involved with SA loss.

There are also several recommendations which could be made for improving this research. The main way in which this research could be improved is through a more developed scoring protocol for analyzing the incident reports and by giving raters more training. These considerations would undoubtedly increase the reliability of the scoring procedure. Also, the reports used in this study came from a specific time period when weather can be extremely bad in the United States. Thus, future work should be conducted using reports which are randomly sampled from numerous time periods

throughout the year to control for, among other factors, the possible effects of weather.

Future research should also seek to replicate the findings of this study. As the investigation of SA and SA errors is a fairly new research area, more research should be conducted to confirm these findings so that the information can be put to practical use. However, while these findings may be new, they are extremely important because they have the potential to impact SA for the safe operation of flight. While not one person died in any of the 590 incident reports used in this study, incidents can easily become accidents. This research has specific applications for flight safety.

APPENDICES

Appendix A

Sample ASRS Incident Report Form

PLEASE FILL IN APPROPRIATE SPACES AND CHECK ALL ITEMS WHICH APPLY TO THIS EVENT OR SITUATION.

REPORTER	FLYING TIME	CERTIFICATES/RATINGS		ATC EXPERIENCE	
o Captain	total ______ hrs.	o student	o private	o FPL	o Developmental
o First Officer		o commercial	o ATP	radar ______ yrs.	
o pilot flying	last 90 days ______ hrs.	o instrument	o CFI	non-radar ______ yrs.	
o pilot not flying		o multiengine	o F/E	supervisory ______ yrs.	
o Other Crewmember	time in type ______ hrs.	o ______		military ______ yrs.	

AIRSPACE		WEATHER		LIGHT/VISIBILITY		ATC/ADVISORY SERV.	
o Class A (PCA)	o Special Use Airspace	o VMC	o ice	o daylight	o night	o local	o center
o Class B (TCA)	o airway/route ______	o IMC	o snow	o dawn	o dusk	o ground	o FSS
o Class C (ARSA)	o unknown/other ______	o mixed	o turbulence	ceiling ______ feet		o apch	o UNICOM
o Class D (Control Zone/ATA)	______	o marginal	o tstorm	visibility ______ miles		o dep	o CTAF
o Class E (General Controlled)	______	o rain	o windshear	RVR ______ feet		Name of ATC Facility:	
o Class G (Uncontrolled)	______	o fog	o ______			______	

	AIRCRAFT 1			AIRCRAFT 2		
Type of Aircraft (Make/Model)	(Your Aircraft) ______		o EFIS o FMS/FMC	(Other Aircraft) ______		o EFIS o FMS/FMC
Operator	o air carrier o commuter	o military o private	o corporate o other ______	o air carrier o commuter	o military o private	o corporate o other ______
Mission	o passenger o cargo	o training o pleasure	o business o unk/other ______	o passenger o cargo	o training o pleasure	o business o unk/other ______
Flight plan	o VFR o IFR	o SVFR o DVFR	o none o unknown	o VFR o IFR	o SVFR o DVFR	o none o unknown
Flight phases at time of occurrence	o taxi o takeoff o climb	o cruise o descent o approach	o landing o missed apch/GAR o other ______	o taxi o takeoff o climb	o cruise o descent o approach	o landing o missed apch/GAR o other ______
Control status	o visual apch o controlled o no radio	o on vector o none o radar advisories	o on SID/STAR o unknown	o visual apch o controlled o no radio	o on vector o none o radar advisories	o on SID/STAR o unknown

If more than two aircraft were involved, please describe the additional aircraft in the "Describe Event/Situation" section.

LOCATION	CONFLICTS
Altitude ______ o MSL o AGL	Estimated miss distance in feet: horiz ______ vert ______
Distance and radial from airport, NAVAID, or other fix ______	Was evasive action taken? o Yes o No
______	Was TCAS a factor? o TA o RA o No
Nearest City/State ______	Did GPWS activate? o Yes o No

DESCRIBE EVENT/SITUATION

Keeping in mind the topics shown below, discuss those which you feel are relevant and anything else you think is important. Include what you believe really caused the problem, and what can be done to prevent a recurrence, or correct the situation. (CONTINUE ON THE OTHER SIDE AND USE ADDITIONAL PAPER IF NEEDED)

CHAIN OF EVENTS	HUMAN PERFORMANCE CONSIDERATIONS
- How the problem arose - How it was discovered	- Perceptions, judgments, decisions - Actions or inactions
- Contributing factors - Corrective actions	- Factors affecting the quality of human performance

FIRST FOLD

NASA ARC 277B (January 1994)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1994-585-800

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AVIATION SAFETY REPORTING SYSTEM

NASA has established an Aviation Safety Reporting System (ASRS) to identify issues in the aviation system which need to be addressed. The program of which this system is a part is described in detail in FAA Advisory Circular 00-46D. Your assistance in informing us about such issues is essential to the success of the program. Please fill out this postage free form as completely as possible, fold it and send it directly to us.

The information you provide on the identity strip will be used only if NASA determines that it is necessary to contact you for further information. THIS IDENTITY STRIP WILL BE RETURNED DIRECTLY TO YOU. The return of the identity strip assures your anonymity.

Section 91.25 of the Federal Aviation Regulations (14 CFR 91.25) prohibits reports filed with NASA from being used for FAA enforcement purposes. This report will not be made available to the FAA for civil penalty or certificate actions for violations of the Federal Air Regulations. Your identity strip, stamped by NASA, is proof that you have submitted a report to the Aviation Safety Reporting System. We can only return the strip to you, however, if you have provided a mailing address. Equally important, we can often obtain additional useful information if our safety analysts can talk with you directly by telephone. For this reason, we have requested telephone numbers where we may reach you.

Thank you for your contribution to aviation safety.

NOTE: AIRCRAFT ACCIDENTS SHOULD NOT BE REPORTED ON THIS FORM. SUCH EVENTS SHOULD BE FILED WITH THE NATIONAL TRANSPORTATION SAFETY BOARD AS REQUIRED BY NTSB Regulation 830.5 (49CFR830.5).

DESCRIBE EVENT/SITUATION (continued):

SECOND FOLD

SECOND FOLD

Appendix B

Incident Report Scoring Protocol

Fill in the blanks with appropriate information or check which option is applicable.

Report Number __________

1) Determine if poor SA quality exists in the report.

-the individual or team may fail to get needed information, fail to understand what perceived information means, or fail to make a prediction of actions based on an understanding of the information received

2) Determine who was involved primarily with the failure to maintain Situation Awareness. Use the following categories (aircrew, gndcrew, tower)

3 a) Categorize the Situation Awareness error using the scale provided by rating the degree to which the error fits into each of the three Levels listed. As reports may have numerous SA errors, please rate how the most prominent or overarching SA error fits into each of the categories listed.

Level 1 error: **perception problem**; failure to perceive available information important to task, person recognizes error as it occurs

error absolutely does not fall into this level category	1	2	3	4	5	error absolutely falls into this level category

Level 2 error: **comprehension problem**; inability to integrate information, misreading of perceived cues available

error absolutely does not fall into this level category	1	2	3	4	5	error absolutely falls into this level category

Level 3 error: **projection of future status problem**; lack of mental simulation of actions before decision is made, understands information presented but fails to project how that will affect the flight (seeing mountain, understanding it will not be cleared, yet flying toward it anyway)

error absolutely does not fall into this level category	1	2	3	4	5	error absolutely falls into this level category

Provide a brief description of the SA error committed:

____

____

____

3 b) Was bad information passed to the operators in the incident, or was no information readily available for SA to exist?

Yes ____ No____

4) Did only one person lose awareness or the entire crew in the SA error?

Team ______ Individual______ Unable to Determine______

5) Was poor communication a factor affecting the SA error? Is communication cited by the reporters as a factor affecting the SA error or is it apparent that it is a factor?

Poor communication: Crew members state that people are not sharing information that is necessary for flight task accomplishment (e.g. PNF not relaying information from tower to PF) or not sharing information in a timely manner

Good Communication: Crew members state that they are sharing information in a timely fashion (before or as the information is needed)

Unable to determine: no apparent evidence is provided relating that poor communication was a factor affecting the error.

Poor communication_____ Poor communication between members in the cockpit________

Poor communication between crew and others outside the cockpit (ie, tower)_________

Good Communication______

Unable to Determine_____

6) Check off the other factors noted by the crew members which you feel affected the SA error.

______Improper procedure:	Did an individual or team perform actions which should not have occurred during the flight?
______ Aircraft equipment malfunctions:	Does some form of equipment malfunction occur prior to or in conjunction with the error in SA?
______Unfamiliarity/ Lack of experience:	Do the pilot(s) cite their unfamiliarity or lack of experience with the aircraft, flying, crewmembers which affected the SA error?
______Weather:	Does the crewmember(s) cite weather as a factor affecting the error?
______Fatigue:	Does the crewmember(s) cite fatigue as a factor affecting the error?
______Night Conditions:	Does the crewmember(s) cite night conditions as a factor affecting the error?
______Emotions:	Does the crewmember(s) cite being upset or angry as a factor affecting the error?
______Distraction:	Does the crewmember(s) cite outside sources as taking them away from their duties to fly the aircraft?

7) Was high workload a factor affecting the SA error? Is high workload cited by the reporters as a factor affecting the SA error or is it apparent from the language of the report?

High Workload: Crewmembers state they were very busy during flight operations at the time of the incident, or there is apparent evidence that the incident occurred during a busy portion of the flight. Extra duties above normal operating procedures are occupying the crewmember(s) attention.

Low Workload: Crewmembers state or give an indication that the workload in the cockpit was normal and not adversely affecting the flight.

Unable to Determine: No apparent evidence is provided relating that flight operations are overly busy

High Workload______ Low Workload_______ Unable to Determine_______

8) Was time pressure a factor affecting the SA error? Is time pressure cited by the reporters as a factor affecting the SA error or is it apparent from the language of the report?

High time pressure: Crewmember(s) state they felt time pressure affected the flight when the SA error occurred, apparent that crewmember(s) rushed through procedures to meet flight demands.

Low time pressure: Crewmembers state or indicate that time pressure was normal when the incident occurred and did not adversely affect the flight

Unable to Determine: Crewmembers do not state they felt time pressure affected the flight or no apparent evidence is provided relating that time pressure is a factor affecting the incident

High Time Pressure____ Low Time Pressure_____ Unable to Determine_____

9) Indicate the phase of flight in which the incident occurred. Circle the appropriate phase.

Preflight	Taxi-out	Takeoff	Climb	Cruise
Descent	Approach	Landing	Taxi-In	Unable to Determine

Appendix C

Sample Data

Level 1 SA Data

Assession Number	team	poor communication	improper procedure	equipment problem	unfamiliarity	weather	fatigue	night	emotions	distraction	high workload	high time pressure
324380	0	0	1	0	0	0	0	0	0	0	0	1
324090	0	1	1	0	0	0	0	0	0	0	1	0
324245	0	0	0	0	0	1	0	0	0	0	0	0
324248	0	0	0	0	1	0	0	0	0	0	0	1
324568	0	1	1	0	0	1	0	0	0	1	0	0
324640	0	0	1	0	0	0	0	0	0	1	0	0
324790	0	1	1	0	0	0	0	0	0	0	0	0
324869	0	0	0	0	0	0	0	1	0	0	0	0
324895	0	0	0	0	0	1	0	1	0	0	0	0
324908	0	0	0	0	0	1	0	1	0	0	0	0
324970	0	0	1	0	0	0	1	0	0	0	0	0
325030	0	0	1	0	0	0	0	0	0	0	0	1
325040	0	0	1	0	0	0	0	0	0	1	0	0
325042	0	0	0	0	0	1	0	0	0	0	0	0
325077	0	0	0	0	0	0	0	0	0	0	0	0
325129	0	0	1	0	0	0	0	1	0	0	0	0
325160	0	0	0	0	1	0	0	0	0	0	0	0
325247	0	0	0	0	0	1	0	1	0	0	0	0
325350	0	0	1	1	0	0	0	0	0	1	0	0
325726	0	0	0	0	0	1	0	1	0	0	0	0
325745	0	0	1	0	0	1	0	0	0	0	0	0
326220	0	0	1	0	0	0	1	1	0	0	0	0
326914	0	1	1	1	0	0	0	0	0	0	0	1
326939	0	0	0	0	0	0	0	0	0	0	0	1
327086	0	0	1	0	0	0	0	0	0	1	0	0
327873	0	0	0	0	0	0	0	0	0	0	0	0
327891	0	0	0	0	0	0	0	0	1	1	0	1
328042	0	0	0	0	0	0	0	0	0	0	0	0
328051	0	1	0	0	1	0	0	0	0	0	0	1
328149	0	1	1	0	0	0	0	0	0	0	0	1
328347	0	1	1	0	0	0	0	0	0	0	0	1
328921	0	0	1	0	0	0	1	1	0	1	0	0
330045	0	0	0	0	0	0	0	1	0	0	0	0
330144	0	0	1	0	1	0	0	0	0	0	0	0
330337	0	0	1	0	0	0	0	0	0	0	0	0
330495	0	0	0	0	0	0	0	0	0	0	0	0
330991	0	0	0	0	0	1	0	1	0	1	0	0
331822	0	0	0	0	1	0	0	1	0	1	0	0
332048	0	0	0	0	0	0	0	0	0	0	0	0
333008	0	0	0	1	0	0	0	0	0	0	0	0
333132	0	0	0	1	0	1	0	0	0	0	1	1
324379	1	0	1	0	0	0	0	1	0	0	0	0
324458	1	1	1	0	0	0	0	0	0	1	1	0
324116	1	0	0	0	0	1	1	1	0	0	0	0
324130	1	1	1	0	1	1	0	1	0	0	0	0
324210	1	0	0	1	0	0	0	0	0	1	1	0
324481	1	0	1	0	0	0	0	0	0	1	0	0
324510	1	1	0	0	0	0	0	0	0	0	0	0
324653	1	1	1	0	0	0	0	0	0	1	0	0
324655	1	0	1	0	0	0	1	0	0	0	0	1
324920	1	0	1	0	0	0	1	0	0	1	0	0
324990	1	0	1	0	0	0	0	0	0	0	0	0
325010	1	0	0	0	0	0	0	0	0	1	0	0
325083	1	0	1	0	0	0	0	0	0	0	0	0
325095	1	0	1	0	0	1	0	0	0	1	0	0
325142	1	0	0	0	0	1	0	0	0	0	0	1
325226	1	0	1	0	0	1	0	0	0	0	0	1
325363	1	1	1	0	0	0	0	0	0	0	0	1
325593	1	0	0	0	0	1	0	0	0	0	0	0
326501	1	0	0	0	0	1	0	0	0	0	0	0
326539	1	0	0	0	0	0	0	0	0	1	0	0
326732	1	0	0	0	0	1	0	0	0	0	0	0
328013	1	0	0	0	0	1	0	1	0	0	0	0
328025	1	0	0	0	0	1	0	1	0	0	1	0
328856	1	0	0	0	0	0	0	0	0	0	1	0
329046	1	1	0	1	0	1	0	0	0	0	0	0
329108	1	0	0	0	1	1	0	0	0	0	0	1
329327	1	0	0	0	1	0	0	0	0	0	1	0
329345	1	0	0	0	0	0	0	1	0	1	0	0
329446	1	0	0	0	0	0	0	0	0	0	0	0
330259	1	0	0	0	0	1	0	1	0	0	0	0
331675	1	1	0	1	0	0	0	0	0	1	0	0
332804	1	0	0	0	0	0	0	0	0	0	0	0
333433	1	0	0	0	0	0	0	0	0	0	0	0
324062	0	0	0	0	0	0	0	0	0	0	0	0
329992	0	0	0	1	0	1	0	0	0	0	1	0
324600	1	1	0	0	0	0	0	0	0	0	0	0
324608	1	1	0	1	0	0	0	1	0	0	0	0
324620	1	0	1	0	0	0	0	0	0	0	0	0
324630	1	0	0	0	0	1	0	0	0	0	0	0
324684	1	1	1	0	0	1	1	0	0	1	0	1
324381	0	0	0	0	0	1	1	0	0	1	1	0
324176	0	0	0	0	0	0	0	1	0	0	0	0
324625	0	0	0	0	0	1	1	1	0	0	0	0
324930	0	1	1	0	0	0	0	0	0	1	1	0
324360	1	0	0	0	0	0	0	0	0	0	0	0
324087	1	1	0	0	1	0	0	0	0	1	1	1
324120	1	0	1	0	0	1	0	0	0	0	0	0
324468	1	0	0	0	0	0	0	0	0	0	0	0
324849	1	0	1	1	0	0	1	1	0	0	1	0
325300	1	0	0	0	0	0	0	0	0	1	0	0
331818	1	0	0	0	0	1	0	0	0	0	0	0
325782	1	0	0	0	1	1	0	0	0	0	0	0
331810	1	0	0	0	0	0	0	0	0	1	0	0
325031	0	0	0	0	1	1	0	0	0	0	0	1

Level 2 SA Data

Assession Number	team	poor communication	improper procedure	equipment problem	unfamiliarity	weather	fatigue	night	emotions	distraction	high workload	high time pressure
331810	1	0	0	0	0	0	0	0	0	1	0	0
328290	1	1	0	0	0	1	0	0	0	0	0	0
333985	1	0	0	0	0	0	0	0	0	0	0	0
324331	0	0	0	1	0	0	0	0	0	1	1	0
324253	0	1	1	0	0	0	0	0	0	0	0	0
324650	0	0	1	0	0	1	0	0	0	1	1	0
324786	0	0	0	0	1	0	0	1	0	0	0	0
325150	0	0	1	0	0	0	0	0	0	0	0	1
325250	0	0	0	0	1	0	0	0	0	0	0	0
325784	0	1	0	0	0	1	0	1	0	0	0	0
330819	0	0	1	0	0	1	1	0	0	0	0	1
324652	1	0	1	0	1	1	0	1	0	0	1	1
325168	1	1	0	0	0	0	0	0	0	0	0	0
327109	1	0	0	0	0	0	0	1	0	0	0	0
327111	1	1	0	0	0	0	0	0	0	0	0	0
327113	1	1	1	0	1	0	0	1	0	1	1	1
329476	1	0	1	0	1	0	0	0	0	1	0	0
329507	1	0	0	0	0	0	0	0	0	0	0	0
324100	0	0	1	0	1	0	0	0	0	1	1	0
324178	0	0	0	0	0	0	1	0	0	0	0	0
324386	0	0	0	1	0	1	0	0	0	0	1	1
324664	0	1	1	0	0	0	0	1	0	0	0	0
324760	0	1	1	0	0	0	0	0	0	0	0	1
325219	0	0	1	0	1	0	0	0	0	0	0	0
326143	0	0	1	0	0	0	0	0	0	0	0	0
326159	0	0	0	0	0	1	0	0	0	0	0	0
324320	1	0	0	0	0	0	0	0	0	0	1	0
324420	1	1	1	0	0	0	0	0	0	0	0	0
325215	1	0	0	0	0	0	0	1	0	0	1	1
326706	1	1	0	0	0	0	0	0	0	0	0	0
329213	1	1	0	0	1	1	0	0	0	1	1	0
324500	0	1	0	0	1	1	0	0	0	1	0	0
324598	1	1	1	0	0	1	0	0	0	1	1	1
324350	0	0	0	0	0	1	0	0	0	0	0	0
324160	0	1	1	1	1	1	0	0	0	1	0	1
324310	0	0	0	0	1	0	0	0	0	0	0	0
324400	0	0	0	0	0	1	0	1	0	0	0	0
324140	0	0	1	0	0	0	0	0	0	0	0	0
324190	0	1	1	0	0	1	0	0	0	1	1	1
324770	0	1	1	0	1	1	0	0	1	0	1	0
324831	0	0	1	0	1	1	0	0	0	0	0	0
324860	0	0	1	0	0	0	0	0	0	1	0	1
324938	0	0	0	1	0	0	0	0	0	0	0	1
325166	0	1	0	0	0	0	0	0	0	0	0	0
325308	0	1	1	1	1	0	0	1	0	0	1	0
325497	0	0	0	0	1	0	0	0	0	0	0	0
327023	0	0	1	0	0	0	0	0	0	0	0	0
329617	0	0	0	1	0	1	0	1	0	0	0	0
330258	0	1	1	0	0	0	0	0	0	1	0	0
331167	0	1	1	0	0	0	0	0	0	0	0	0
324200	1	0	0	0	0	0	0	0	0	0	0	0
324710	1	0	0	0	0	0	0	0	0	0	0	0
324775	1	0	0	0	1	0	0	1	0	0	0	0
324810	1	0	0	0	0	0	0	0	0	0	0	0
325091	1	1	0	0	0	0	0	0	0	0	0	0
325292	1	1	0	0	1	1	0	0	0	0	1	0
325310	1	0	0	0	1	0	0	0	0	0	0	0
325311	1	1	0	1	0	0	0	0	0	0	0	0
325330	1	1	1	0	1	0	0	0	0	0	0	1
325340	1	1	1	0	0	0	0	0	0	0	0	0
325379	1	0	0	0	0	0	0	0	0	0	1	1
326052	1	0	0	0	0	1	0	0	0	0	1	0
326807	1	1	0	0	0	0	0	0	0	0	0	0
326844	1	1	1	0	0	0	0	0	0	0	0	0
328569	1	0	0	0	1	0	0	1	0	0	1	0
329197	1	0	0	0	0	1	0	1	0	0	0	0
329892	1	1	1	0	0	1	1	0	0	0	0	0
330977	1	1	1	0	0	1	0	0	0	1	0	1
331026	1	0	1	0	0	0	0	0	0	0	0	0
331284	1	0	0	0	0	1	1	1	0	0	0	0
322004	1	0	0	0	0	0	0	0	0	0	0	0
332227	1	1	1	0	1	0	0	0	0	0	0	0
332819	1	0	0	0	1	0	0	0	0	0	0	1
333188	1	0	0	0	0	1	0	0	0	0	0	0
333271	1	0	0	0	0	0	0	0	0	0	0	0
333855	1	0	0	0	0	0	0	0	0	0	0	0
325085	0	0	0	1	1	0	0	0	0	0	0	1
325130	0	0	1	0	0	0	0	1	0	0	0	0
324964	1	1	1	0	1	1	0	0	0	0	1	0
324980	0	0	1	0	1	0	0	0	0	0	0	1
325169	0	0	0	0	0	1	0	0	0	0	0	1
324801	1	1	1	0	0	0	0	0	0	0	0	0
325170	1	1	1	0	0	0	0	0	0	0	0	0
328150	1	1	1	0	0	0	0	0	0	0	0	0
332010	0	0	0	0	1	0	0	0	0	0	0	0

Level 3 SA Data

Assession Number	team	poor communication	improper procedure	equipment problem	unfamiliarity	weather	fatigue	night	emotions	distraction	high workload	high time pressure
327469	1	1	1	0	0	0	0	0	0	0	0	0
324883	0	0	1	0	1	0	0	0	1	0	0	1
324800	0	0	0	0	1	0	0	1	0	0	0	0
325110	1	0	1	0	0	1	0	0	0	0	0	0
324296	0	0	1	0	1	0	0	0	0	0	0	1
324627	0	1	1	0	1	0	0	0	0	0	0	0
324950	0	0	0	0	0	0	0	0	0	0	0	0
324370	1	0	1	1	1	0	0	0	0	0	0	0
324170	1	1	1	0	0	0	1	0	0	0	0	0
324463	1	0	1	1	0	1	0	0	0	1	1	1
324467	1	1	1	0	0	0	0	0	0	0	0	0
324575	0	1	1	0	0	1	0	0	0	1	1	0
324410	1	1	1	0	0	0	0	0	0	0	1	1
325070	1	0	1	0	0	0	0	0	0	0	0	0
324340	0	0	1	0	0	0	0	0	0	0	0	0
324540	0	0	0	0	0	0	0	0	0	0	0	0
324577	0	0	0	0	0	1	0	0	0	0	0	0
324637	0	1	0	0	0	0	0	0	0	1	0	1
324870	0	0	1	0	0	1	0	0	0	0	0	0
325177	0	0	1	1	0	1	0	0	0	0	0	1
326955	0	0	0	0	0	1	0	0	0	0	0	0
328046	0	0	0	0	0	0	0	1	0	0	0	1
331028	0	0	0	0	0	0	0	1	0	0	0	1
324940	1	0	1	0	1	1	0	1	0	0	0	1
325370	1	1	1	0	0	0	0	0	0	0	1	1
334210	1	0	1	0	0	0	0	0	0	0	0	1

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